NASA High Performance Computing Summer School

Satellite Protection

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Outline

- Introduction
- Overview
- Some Details
- Possible Collaborations
- The Road Ahead

Introduction

The Issue

- Energetic particles and energy fluxes
  - Prevalent throughout near Earth orbits
  - Highly variable
  - Determined by Solar activity
  - Major factor in satellite life
  - ? Can be predicted ?
- Satellite Operations can mitigate the effects
  - Resets
  - Power down
  - Attitude control
  - Orbit change

Motivation

- High energy particles
  - Satellite disorientation
  - Damage to solar power cells
  - Single event upsets
  - Processor latchup
  - Space craft and sensor damage
  - False sensor readings
- Low energy particles
  - Satellite Communication interference
  - Satellite orbit decay
  - Radar false targets
  - Electrical power grid failure
  - Geolocation errors
  - HF interference

Caused by Solar Events

Protecting our Satellite Fleet

- Predictions would be beneficial
  - Occurrence
  - Effects of interactions
  - Based on individual satellites
- Results
  - Increased lifetime
  - Reduced immature failure

Plan for modeling the occurrence of interactions and assessing the lifetime of Satellites

Benefits to NASA

- Provide new research in predictive capability for solar particle events
- Address goal to advance and communicate scientific knowledge and understanding of Earth, the environment of space, the solar system, and the universe
  - Increase understanding of Solar-Earth system
- Address goal to explore, use, and enable the development of space for human enterprise
  - Provide predictive capability for satellite operations

Overview

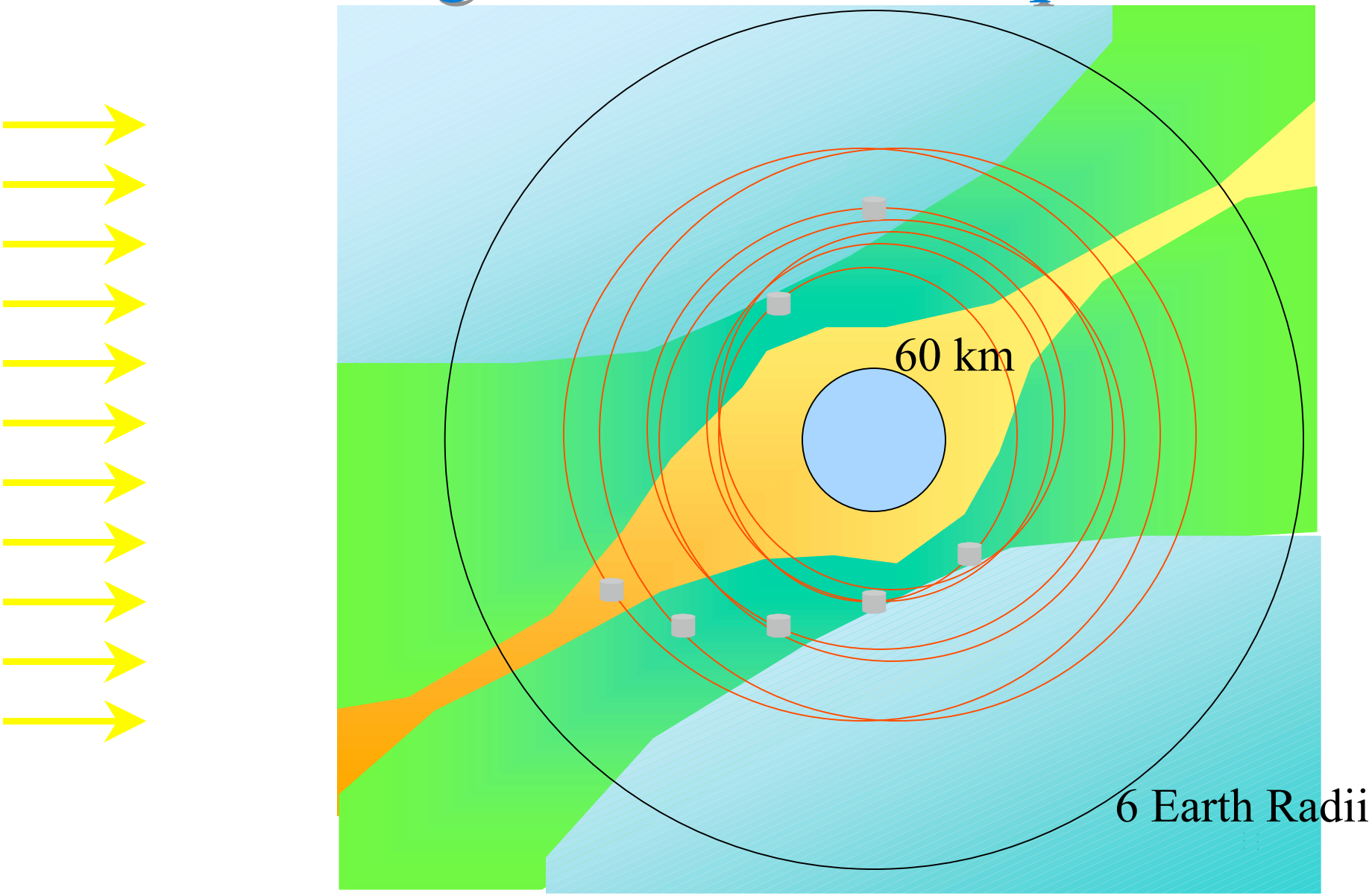
Overall Project Discussion

- Integrate code from several areas
  - Sensor Input
  - Space Weather
  - Magnetization Physics
  - Energy Interactions
  - Orbitology
  - Energetic Particle Deposition and Degradation
- Update models
- Provide visualization to NOAA
- Real Time Computation
- Interface to Sensor and Satellite Operators
- Forecasting

Integrate -- Update -- Visualize -- Predict

Source: Space Environment Center Homepage

Energetic Particle Map



Focus

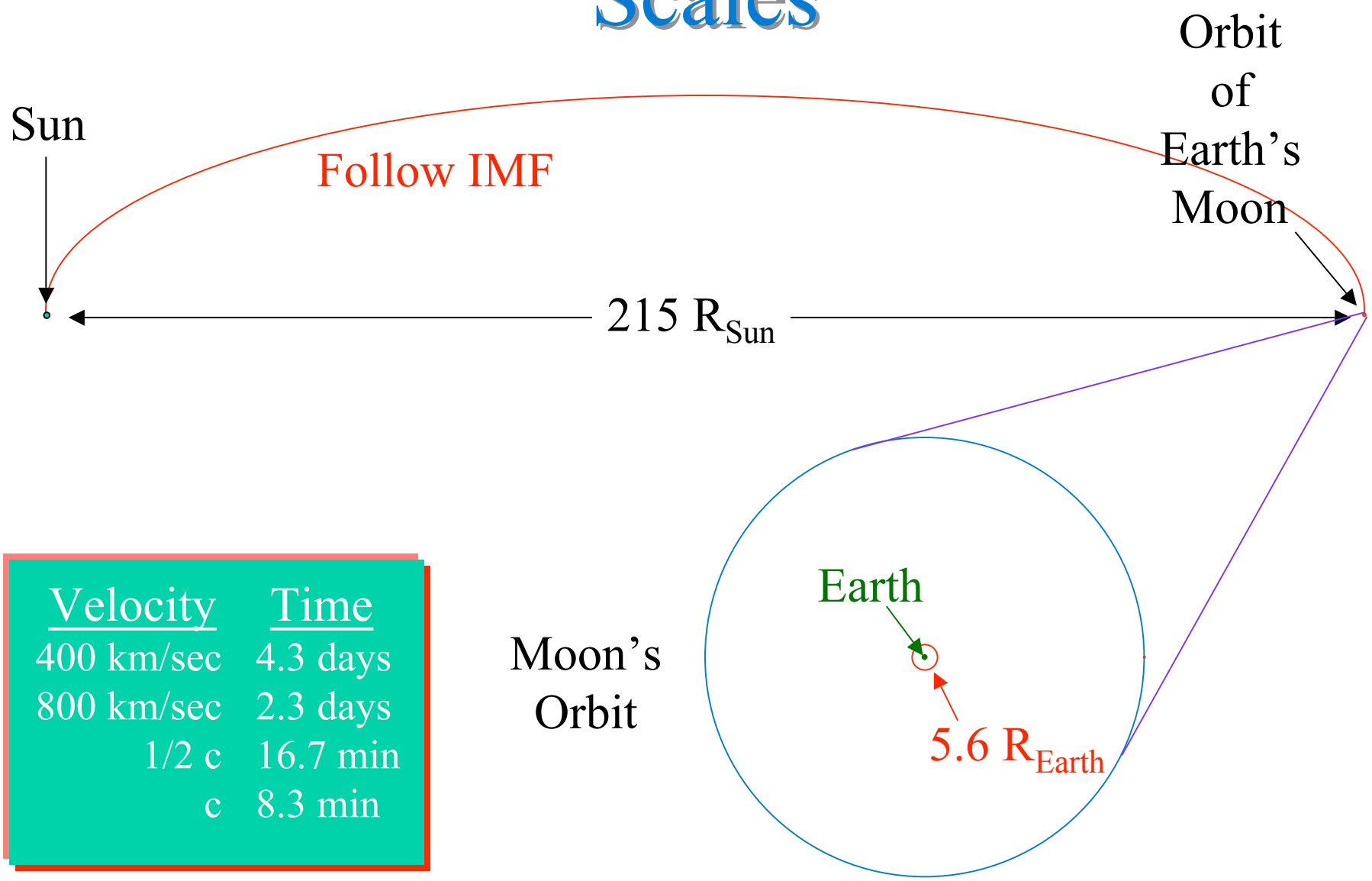
- Output
  - 3-day to 1 hour predictions
  - Updated in real-time
- Issues
  - Relativistic energy here as we measure it
  - Solar wind about 3 days
  - 3-4 days to do computations
- Conclusion
  - Must forecast from solar activity
  - Then update with
    - Observed solar activity
    - Measured solar wind

Some Details

Desired Results

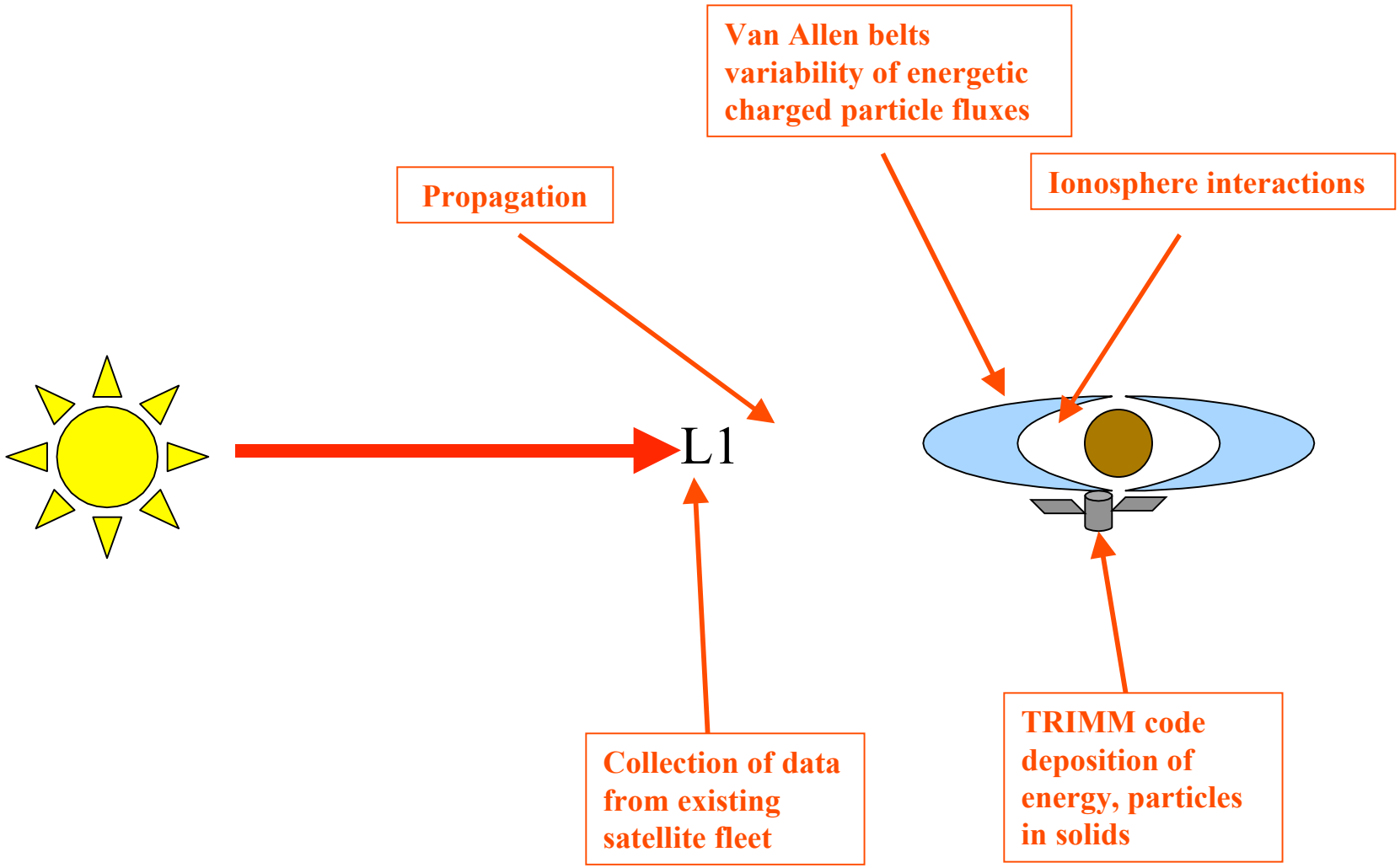
- Modular Computational System
  - Ingest CME/Flare data
  - CME propagation modules
  - MHD + PIC Magnetosphere module coupled to Ionosphere model
  - Collect particle fluxes and energy distribution
  - Visualization
  - 3-day Forecasts
  - Material Effects
- Interactive mapper on NOAA SEC site
- "Accurate" 5-D energy flux predictions
- Notification Service

Scales

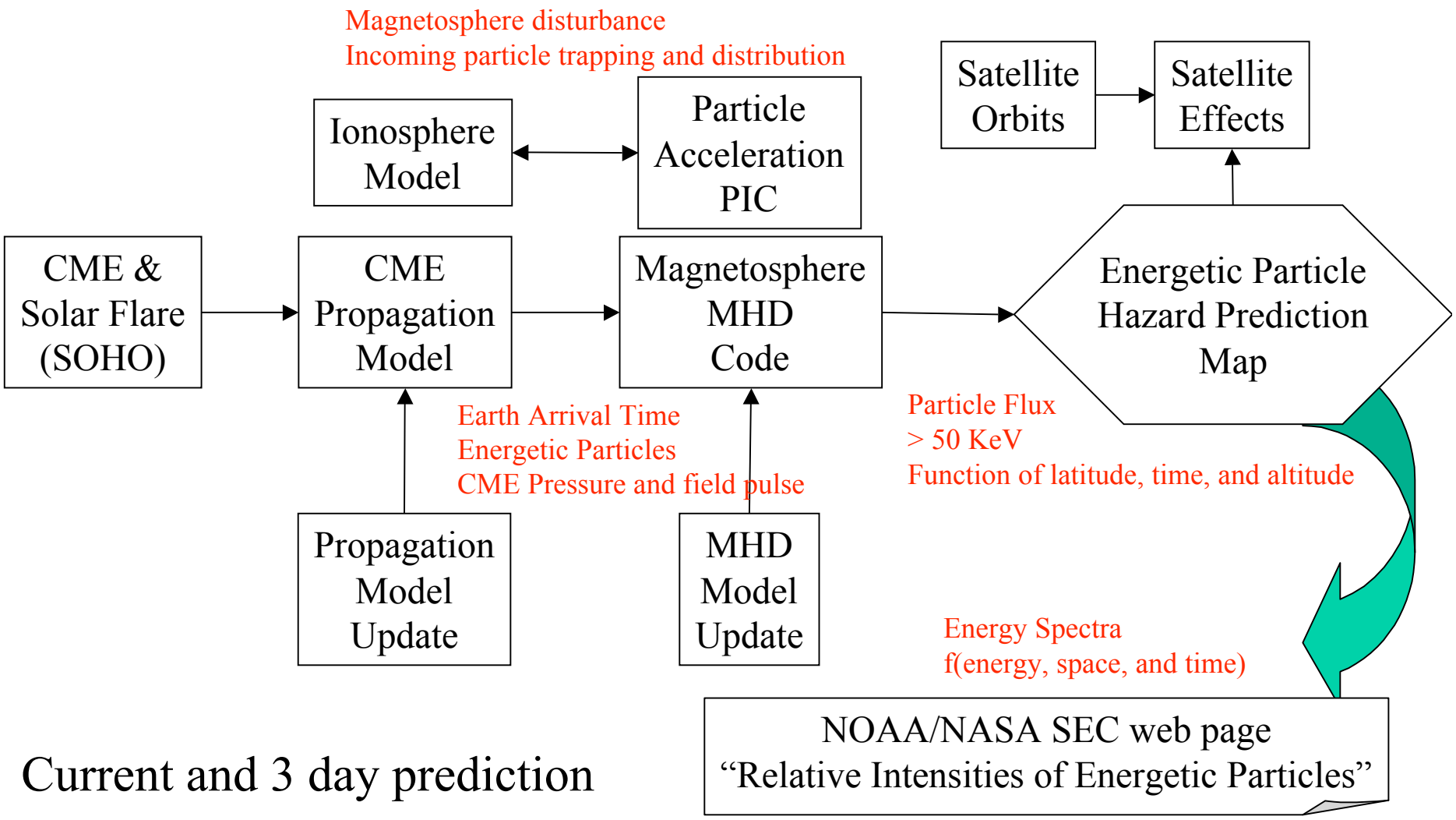


Velocity	Time
400 km/sec	4.3 days
800 km/sec	2.3 days
1/2 c	16.7 min
c	8.3 min

Simple Representation



Overview



Current and 3 day prediction

Areas of Opportunity

- Only crude propagation models exist
- Real time generally not supported
- Many dispersed efforts
- Accuracy, Reliability, Believability
- Interactions with existing satellite fleet

Lots of models available
Varying degrees of realism

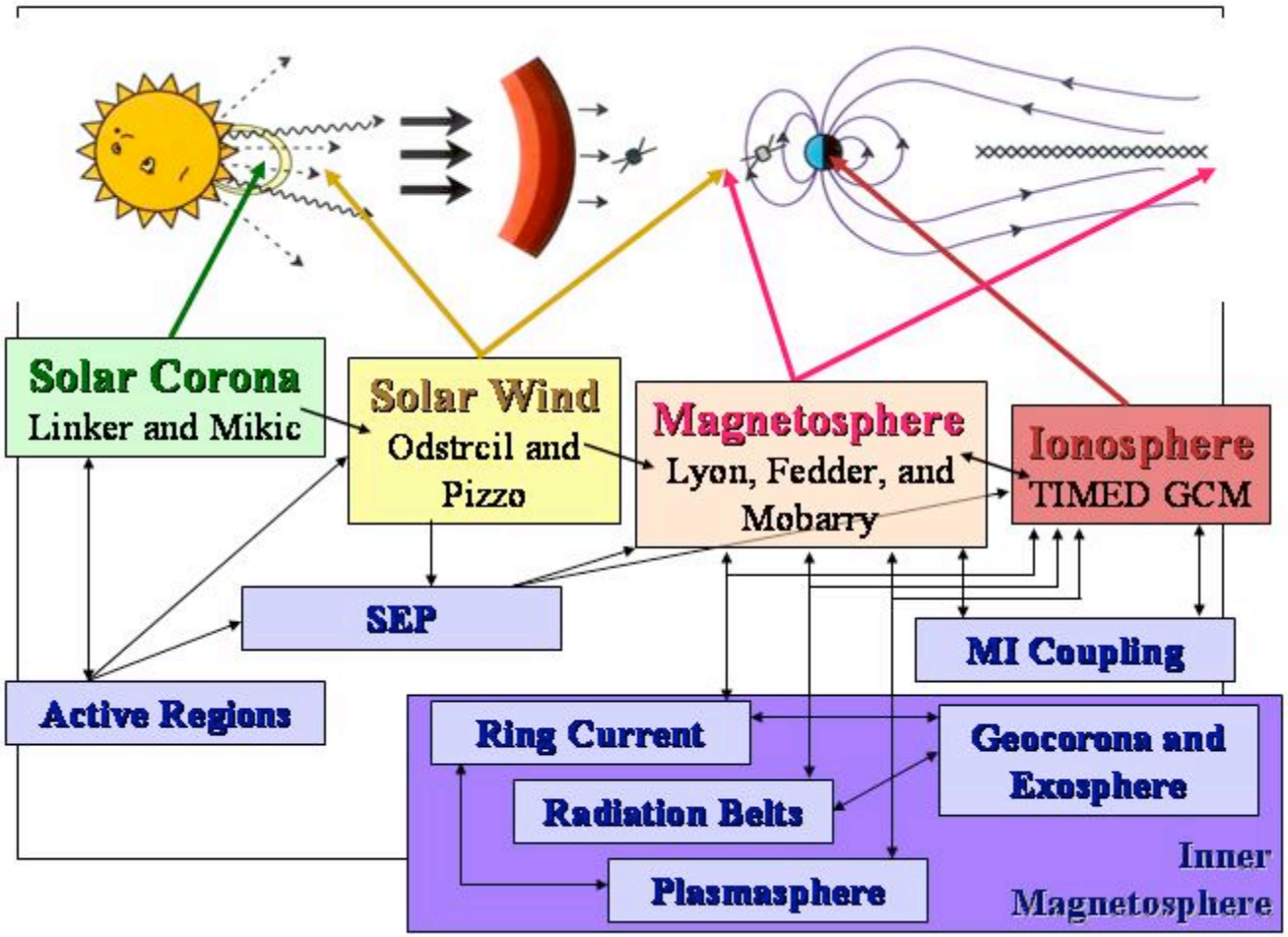
Possible Collaborations

Related Projects

- Center for Integrated Space Weather Modeling (BU)
- Space Weather Modeling Framework (University of Michigan)
- Earth System Modeling Framework

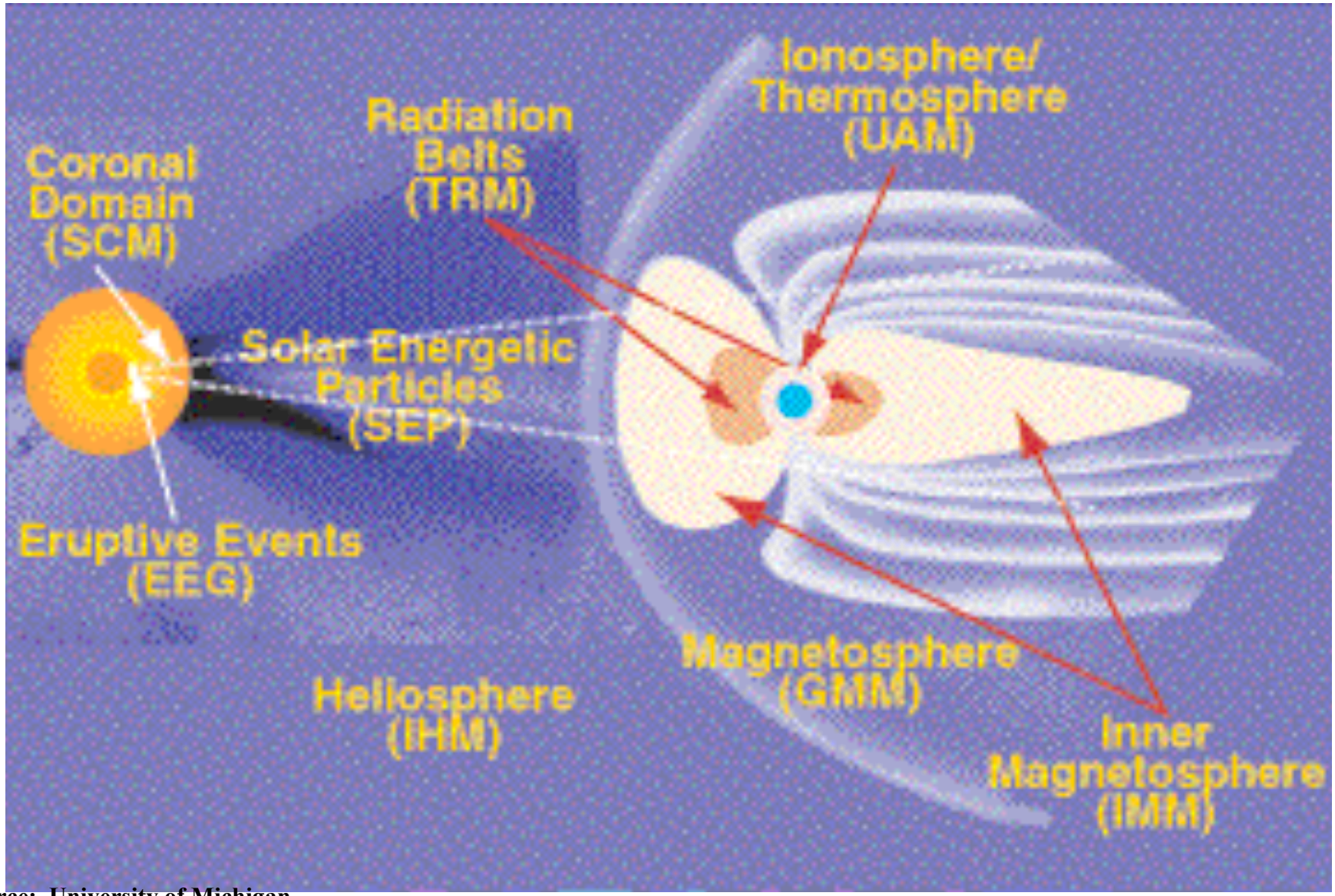
- AFRL
  - Reproduce variability of 0.5 MeV electron flux with time-dependent diffusion model and suitable boundary conditions
- NASA
  - CME arrival prediction
  - Couple of magnetosphere and ionosphere codes
  - Provide data for ACE, GOES, Polar satellite sensor suits
- NOAA
  - PROTONS model
- Future Plans by NASA
  - Radiation belt mapper satellites
  - Energetic particle modeling

CISM



Source: Boston University

SWMF



Source: University of Michigan

The Road Ahead

Current Work

- Collaborate with current efforts
- Integrate orbitology
- Integrate effects
- Tune for Real Time operations
- Ingest actual data
- Prediction

The Future

- New sensors
- Improved space weather codes
- Improved understanding of effects
- Increased automation
- Better understanding of solar phenomena
- Forecasting models